A 3-Dimensional Computed Tomographic Procedure for Planning Retrosigmoid Craniotomy

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OBJECTIVE: The planning of retrosigmoid craniotomies often relies on anatomic landmarks on the posterolateral surface of the cranium, such as the asterion. However, the location of the asterion is not fixed with respect to the underlying transverse-sigmoid sinus complex. We introduce a simple procedure that uses 3-dimensional (3D) computed tomographic imaging to project the transverse-sigmoid sinus complex onto the external surface of the cranium.

METHODS: We enrolled 8 patients scheduled for retrosigmoid craniotomy (Group 1) and 30 patients without posterior fossa lesions (Group 2). The procedure consists of 3 steps: 1) marking the sinus on the internal surface on 3D images of the cranium, 2) transferring the marks to the external surface on axial images, and 3) checking the transferred marks on the external surface of the cranium on 3D images.

RESULTS: In Group 1, the craniotomies planned with the aid of our procedure coincided with findings made at surgery, indicating the accuracy of our procedure. When we applied it in morphometric studies in Group 2, we found that the relative location of the transverse-sigmoid sinus junction to the asterion, the superior nuchal line, and the posterior edge of the mastoid process exhibited a high degree of individual variation.

CONCLUSION: Retrosigmoid craniotomy standardized according to anatomic landmarks raises the risk for sinus injury because of variations in their location. We offer our 3D computed tomographic imaging-based procedure as a useful device for the planning of safer retrosigmoid craniotomies.

KEY WORDS: Retrosigmoid craniotomy, Suboccipital craniotomy, Three-dimensional computed tomographic bone image, Transverse-sigmoid sinus

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In patients undergoing neurosurgical procedures, a safe and appropriate craniotomy is a prerequisite, irrespective of the selected surgical approach. Although supratentorial craniotomies have been standardized, suboccipital craniotomies tend to rely on landmarks on the occipital bone and on the surgeon's experience. Anatomic landmarks such as the asterion, the superior nuchal line, and the posterior edge of the mastoid process have been used to place the first burr hole for a lateral suboccipital craniotomy. However, there is reportedly a high degree of individual variation in the relationship between surface structures and the internal anatomy, raising the risk of sinus injury when they are used as landmarks (5). The sigmoid sinus is easily lacerated during a lateral suboccipital craniotomy, because it often adheres to the bony groove and emissary veins attached to this structure. We encountered patients whose transverse sinus was located high; in these patients, placing the first burr hole based on the bone landmark would produce an unnecessarily large cranial opening (Fig.1).

ABBREVIATIONS: 3D, 3-dimensional; **CT**, computed tomographic; **T-S**, transverse-sigmoid

The purpose of this study is to introduce a method that uses 3-dimensional (3D) computed tomographic (CT) images to locate the transverse-sigmoid (T-S) sinus complex on the surface of the cranial bone. The procedure is simple enough to be performed at preoperative evaluation. We report the relationship between the T-S sinus complex and anatomic

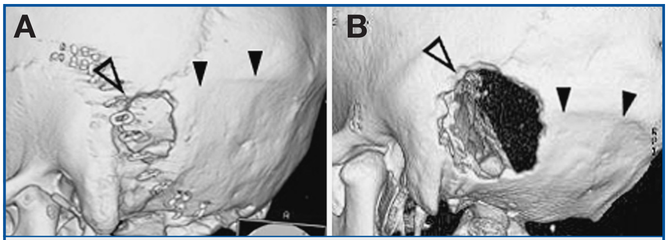

FIGURE 1. *Postoperative 3-dimensional (3D) computed tomographic (CT) bone images of 2 illustrative patients with trigeminal neuralgia who had undergone a retrosigmoid craniectomy.* **A**, *small craniectomy at the corner of the transverse-sigmoid (T-S) sinus complex (open arrow) located exactly on the superior nuchal line (arrowheads).* **B**, *corner of the T-S sinus complex (open arrow), located well above the superior nuchal line in the other patient (arrowheads). This variation in the sinus location resulted in an unnecessarily large craniectomy, because the landmark for placing the first burr hole was the superior nuchal line.*

landmarks on 3D CT bone images, and discuss the applicability of our procedure.

PATIENTS AND METHODS

To test our procedure on patients scheduled for a retrosigmoid craniotomy (Group 1), 8 patients (trigeminal neuralgia, n = 3; meningioma, n = 2; vestibular schwannoma, n = 2; hemangioblastoma, n = 1) were studied before and after surgery. For the measurement study of landmarks on the posterolateral aspect of the cranium (Group 2), we enrolled 30 patients treated at the Department of Neurosurgery between January and February 2008. They were 18 women and 12 men; their mean age was 61.7 ± 21.2 years (age range, 17–86 years). These patients were either scheduled for supratentorial surgery or had undergone a head CT scan to screen for intracranial lesions. None had posterior fossa lesions. As we measured both sides in each patient, we obtained a total of 60 measurements.

Thin-slice, 1.25-mm thick CT images (LightSpeed VCT; General Electric Healthcare, Chalfont St. Giles, England) were reconstructed on an Advantage workstation 4.3 (General Electric Healthcare). The procedure for projecting the sinus complex onto the bone surface consists of 3 steps (Fig. 2). First, on the internal view of the 3D CT image, the groove of the T-S sinus complex, easily identified in all of our patients, is marked with a number of points on the internal surface of the cranium (Fig. 2A). Second, on the axial image, all marks placed on the internal surface are transferred to the external surface in such a way that the line connecting 2 marks is perpendicular to the bone surface. This step is consistent with surgical practice where the bone saw is usually applied perpendicular to the bone surface (Fig. 2B). Thrd, on the external view of the 3D CT image, the outline of the T-S sinus complex is visualized on the bone surface (Fig. 2C).

To determine the location of the asterion in Group 2, we performed a grid study on the workstation using methods described in fixed cadaver heads (3, 6, 7). In brief, after the T-S sinus complex was projected onto the external cranial surface by our procedure, a 3-cm × 3-cm grid was centered over the transverse sinus and the upper curve of the sigmoid sinus (Fig. 3), and the position of the asterion on the grid was recorded. The data were expressed as percentages of the asterion located in each subdivision on the grid.

In Group 2, we performed morphometric analysis using 3D CT bone images. The data were displayed on the workstation, which made it

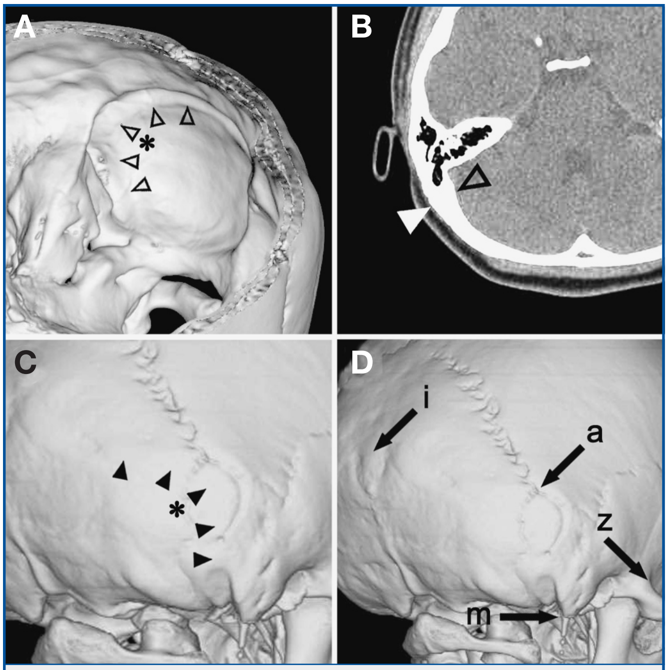

FIGURE 2. *3D CT-based procedure to project the T-S sinus complex onto the external surface of the cranium.* **A**, *internal surface of the right posterior fossa. Open arrows indicate the inner margin of the T-S sinus complex. The asterisk identifies the location of the T-S sinus junction.* **B**, *marks placed on the internal surface (open arrow), transferred to the external surface (white arrow).* **C**, *external surface of the right posterior fossa. Black arrows indicate the inner margin of the T-S sinus complex.* **D**, *anatomic landmarks. "a," "z," "m," and "i" indicate the asterion, the root of the zygoma, the mastoid tip, and the inion, respectively.*

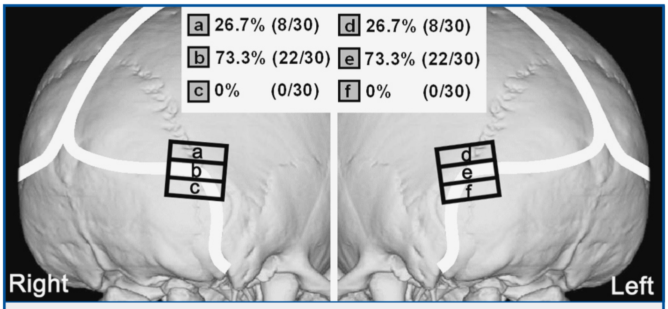

FIGURE 3. *Grid study of the location of the asterion on 3D-CT bone images. A 3 × 3-cm grid is centered over the transverse sinus and the upper curve of the sigmoid sinus after the T-S sinus complex is projected onto the external cranial surface by our 3D CT-based procedure. The data are expressed as percentages of the asterion located in each subdivision on the grid.*

possible to measure the distance between 2 points in 3D space. The distance between the inside corner of the T-S sinus junction (asterisk in Fig. 2C), projected onto the cranial surface, and 4 anatomic landmarks, i.e., the asterion, root of the zygoma, mastoid tip, and inion (Fig. 2D), was measured. The coordinate axis of the superior nuchal line, defined as a line from the external occipital protuberance (i.e., the inion) to the

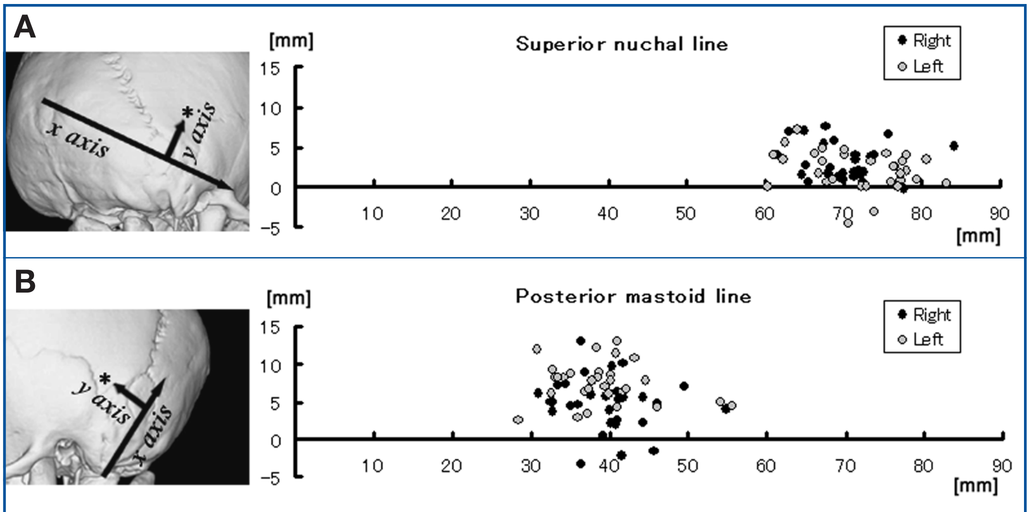

FIGURE 4. *Morphometric analysis of the bilateral T-S sinus junction in relation to the superior nuchal line and the posterior edge of the mastoid process on 3D CT bone images obtained in 30 Group 2 patients.* **A**, *the definition of the coordinate axis in the superior nuchal line study is shown on the left. The x axis extends from the inion to the root of the zygoma, and the y axis is perpendicular and superior to the x axis on the lateral suboccipital aspect of the cranial bone. The location of the inside corner of the T-S sinus junction was projected onto the cranial surface (asterisk) by means of our method and then expressed in the defined coordinate axis. Scatter plots are shown on the right. Black and gray dots indicate data on the right and left of the cranium, respectively.* **B**, *definition of the coordinate axis in the posterior mastoid line study is presented on the left. The x axis is a line starting at the mastoid tip and is drawn along the posterior edge of the mastoid process and the y axis is perpendicular and anterior to the x axis on lateral views of 3D CT images. The data are presented as described in* **A**.

root of the zygoma (2), was drawn on the lateral suboccipital aspect of the cranial bone. The x axis extends from the inion to the root of the zygoma, and the y axis is perpendicular and superior to the x axis (Fig.4A). The coordinate axis of the posterior edge of the mastoid body (designated the posterior mastoid line) was defined on lateral views of 3D CT images (Fig. 4B). Thus, the x axis is a line starting at the mastoid tip and is drawn along the posterior edge of the mastoid process. The y axis is perpendicular and anterior to the x axis. For statistical analysis, we used the unpaired t test and SPSS software (Version 10; SPSS Inc., Chicago, IL) running on a personal computer. A P value of less than 0.05 was considered statistically significant.

RESULTS

We evaluated the reliability of our procedure by comparing pre- and postoperative 3D CT bone images obtained in Group 1. The example shown in Figure 5 demonstrates a good match between the actual and predicted craniotomies. The errors were 3.01 ± 1.97 mm (mean ± standard deviation) in Group 1. We suggest that the sinus projection on 3D CT images is sufficiently precise for practical application at surgical planning.

Our grid study showed that the asterion was located directly on the T-S sinus junction on both sides in 22 of the 30 Group 2 patients (73.3%) (Fig. 3, B and E). It was above the T-S sinus junction, i.e., above the supratentorial dura mater, in the other 8 (26.7%) on both sides (Fig. 3, A and D). In none of the 30 patients was the asterion inferior to the T-S sinus junction; i.e., above the posterior fossa dura mater (Fig. 3, C and F).

The results of our morphometric study are summarized in Table 1. At all values, the standard deviations appeared to be stable; they were between 3.3 and 4.7 mm. The mean distance between the inside corner of the T-S sinus junction and the root of the zygoma on the right was significantly longer than on the left side (51.8 ± 4.5 mm versus 50.0 ± 3.3 mm; $P = 0.040 < 0.05$). In contrast, the mean distance between the inside corner of the T-S sinus junction and the inion on the right was significantly shorter than on the left side (71.1 ± 3.5 mm versus 73.1 ± 5.1 mm; $P = 0.042 < 0.05$). There were no significant right-left differences between the inside corner of the T-S sinus junction and the asterion and the mastoid tip (Table 1).

The results of our study of the coordinate axis are summarized in Table 2; plot data are shown in Figure 4. Study of the superior nuchal line showed that the location of the inside corner of the T-S sinus junction was a mean of 71.1 ± 5.5 mm from the inion, and 2.5 ± 2.4 mm superior to the superior nuchal line. The difference between the maximum and minimum values on the x axis, representing the greatest individual variations on the mediolateral axis, was 23.8 mm. The difference between the maximum and minimum values on the y axis, representing the greatest individual variations on the craniocaudal axis, was 12.1 mm. Study of the posterior mastoid line showed that the location of the inside corner of the T-S sinus junction was a mean of 39.3 ± 5.6 mm from the tip of the mastoid process, and 6.0 ± 3.4 mm anterior to the posterior mastoid line. The difference between the maximum and minimum values on the x axis, representing the greatest individual variations on the craniocaudal axis, was 27.2 mm. Lastly, the difference between the maximum and minimum values on the y axis, representing the greatest individual variations on the mediolateral axis, was 16.2 mm. Right-left side differences were not significant for any of the calculated values, with the exception of the y axis in the posterior mastoid line study ($P = 0.00076 < 0.001 < 0.01$).

DISCUSSION

To access the petroclival region, the retrosigmoid approach is used in vascular, neoplastic, and functional brain surgery. For placement of the entry point into the cranial compartment, localization of the underlying T-S sinus complex is necessary for

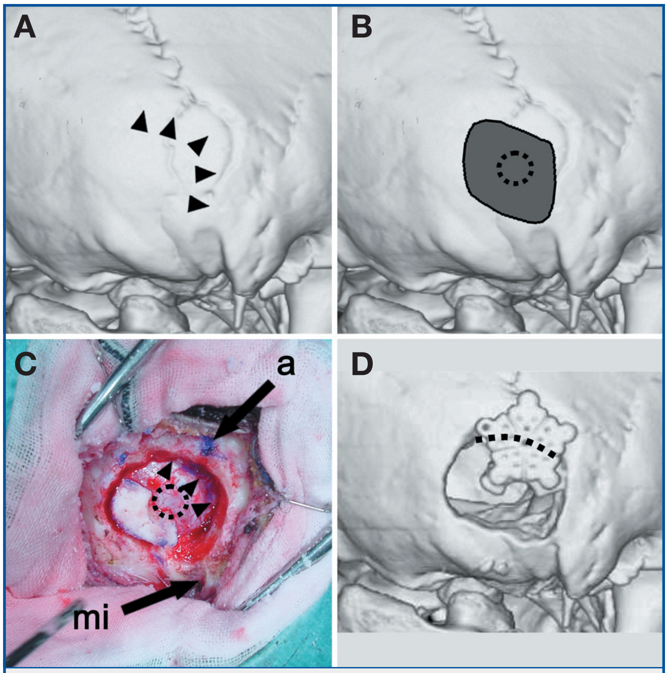

FIGURE 5. *Illustrative case showing the reliability of our procedure.* **A**, *mapping of the T-S sinus complex (arrowheads) before retrosigmoid craniotomy.* **B**, *preoperative planning of the first burr hole (dotted circle) and retrosigmoid craniotomy (gray area).* **C**, *intraoperative photograph. Arrowheads indicate the sigmoid sinus. a, asterion; mi, mastoid incisula.* **D**, *postoperative 3D CT showing the actual craniotomy.*

proper opening of the cranial bone and for minimizing the risk of sinus injury during bone removal (2). Using the reconstruction of 3D CT bone images, we investigated the relationship between surface landmarks and the internal anatomy involved in retrosigmoid craniotomy, and also confirmed the reliability of our method in patients who underwent this procedure (Fig. 5).

The asterion is defined as the junction of the lamboid, parietomastoid, and occipitomastoid sutures. According to Rhoton (4), the first burr hole should be placed 2 cm below the asterion to avoid the sigmoid sinus. Day and Tschabitscher (3), who examined 100 dried human skulls, found that in 68% and 75%, the asterion was located over or above the T-S sinus complex on the right and left, respectively. Thus, if it is used as the landmark for the first burr hole, the transverse/sigmoid sinuses may be injured in more than 50% of patients (7). Yamashita et al. (8) found the asterion to be a useful landmark for their unique small triangular craniectomy via the retrosigmoid approach, altered to normal variations of the posterior fossa. They warned that special attention should be paid in patients in whom the angle of the straight sinus is steep or the angle of the posterior fossa is wide. In 26.7% of our Group 2 patients, the asterion was located above the T-S sinus complex (Fig. 3). Therefore, placement of the first burr hole 1 cm below the asterion risked lacerating the sinus in more than 25% of these patients, considering that the sinus width in this portion is reportedly 10.7 ± 1.4 mm (6). On the other hand, if the burr hole is placed a few centimeters below the asterion, an excessively large cranial opening may be produced (Fig. 1A). These considerations indicate that the asterion is not a suitable landmark for a retrosigmoid craniotomy because of variations in its cephalocaudal position.

Day et al. (2) performed anatomic studies on fixed cadaveric preparations; they concluded that for posterior fossa surgery, the superior nuchal line is a more reliable landmark than the asterion. They reported that the superior nuchal line can be used to mark the inferior border of the transverse sinus, and that the posterior edge of the mastoid process approximates the posterior margin of the descending segment of the sigmoid sinus. Sekhar (5) also detected similar anatomic relationships, and suggested that the first burr hole for the retrosigmoid craniotomy be drilled at the intersection of the superior nuchal and the extension of the posterior mastoid line.

Using 60 bilateral measurements obtained in 30 Group 2 patients, we performed morphometric studies on the coordinate axis along these 2 anatomic lines. In terms of the relative location of the T-S sinus complex vis-a-vis the superior nuchal line, the greatest individual differences were 23.8 and 12.1 mm for the mediolateral and craniocaudal axes, respectively (Fig. 4A). The variation in the mediolateral axis was more than twice the mean width of the sinus in this portion (6). It is not always easy to pinpoint the location of the superior nuchal line on the cranial surface, because the inion and the root of the zygoma are usually outside the surgical field; this is another disadvantage of using the superior nuchal line as a landmark line. The

TABLE 1. Distance between the inside corner of the transverse-sigmoid sinus junction and anatomic landmarks on the posterolateral cranial surface[a]

Anatomic landmarks	Asterion (mm)	Zygoma root (mm)	Mastoid tip (mm)	Inion (mm)
Right side	13.4 ± 4.7	51.8 ± 4.5	39.8 ± 4.5	71.1 ± 3.5
Left side	14.2 ± 3.6	50.0 ± 3.3	39.3 ± 3.7	73.1 ± 5.1
Total	13.8 ± 4.2	50.9 ± 4.1	39.6 ± 4.1	72.1 ± 4.5
Right-left difference[b]	0.222	0.040[c]	0.323	0.042[c]

[a] Distances are expressed as the mean ± standard deviation.
[b] Expressed as the *P* value of unpaired *t* tests.
[c] $P < 0.05$.

TABLE 2. Morphometric analysis on the inside corner of the transverse-sigmoid sinus junction in relation to the defined landmark lines on the posterolateral cranial surface

Landmark lines	Superior nuchal line[a,b]		Posterior mastoid line[a,b]	
	x axis (mm)	y axis (mm)	x axis (mm)	y axis (mm)
Right side	70.5 ± 4.7	2.9 ± 2.2	39.6 ± 5.3	4.7 ± 3.5
Left side	71.8 ± 6.3	2.1 ± 2.5	39.0 ± 5.9	7.4 ± 2.7
Total	71.1 ± 5.5	2.5 ± 2.4	39.3 ± 5.6	6.0 ± 3.4
Right-left difference[c]	0.171	0.090	0.348	0.001[d]

[a] The *x* and *y* axes are defined as shown in Figure 4.
[b] Data are expressed as the mean ± standard deviation.
[c] Expressed as the *P* value of unpaired *t* tests.
[d] $P < 0.01$.

location of the T-S sinus complex was more widely distributed in relation to the posterior mastoid line (Fig. 4B). In terms of the relative location of the T-S sinus complex to the posterior mastoid line, the greatest individual differences were 16.2 and 27.2 mm for the mediolateral and craniocaudal axes, respectively (Fig. 4B). We posit that the higher degree of individual variation is partly a result of differences in the shape of the mastoid process and in the angle of the posterior mastoid line to the cranial surface. The variations in relation to the mastoid process are also consistent with the finding that regional mastoid pneumatization correlated with the position of the sigmoid sinus (1). We suggest that the planning of retrosigmoid craniotomy using these 2 anatomic lines as landmarks may present the risk of sinus injury because of the high degree of their individual variations.

CONCLUSIONS

Our simple, reliable 3D CT-based method yields information facilitating the placement of safe and appropriate cranial openings. We reconfirmed that the asterion is not a reliable landmark for locating the underlying T-S sinus complex. Furthermore, the corner of the T-S sinus complex is not always on the intersection of the superior nuchal line and the line drawn from the posterior edge of the mastoid process. Using our method at the preoperative examination may help to avoid the risk of sinus injury in patients undergoing a retrosigmoid craniotomy.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Aslan A, Kobayashi T, Diop D, Balyan FR, Russo A, Taibah A: Anatomical relationship between position of the sigmoid sinus and regional mastoid pneumatization. **Eur Arch Otorhinolaryngol** 253:450–453, 1996.
2. Day JD, Kellogg JX, Tschabitscher M, Fukushima T: Surface and superficial surgical anatomy of the posterolateral cranial base: Significance for surgical planning and approach. **Neurosurgery** 38:1079–1084, 1996.
3. Day JD, Tschabitscher M: Anatomic position of the asterion. **Neurosurgery** 42:198–199, 1998.
4. Rhoton AL Jr: Surface and superficial surgical anatomy of the posterolateral cranial base: Significance for surgical planning and approach. **Neurosurgery** 38:1083–1084, 1996 (comment).
5. Sekhar LN: Anatomic position of the asterion. **Neurosurgery** 42:198–199, 1998 (comment).
6. Ucerler H, Govsa F: Asterion as a surgical landmark for lateral cranial base approaches. **J Craniomaxillofac Surg** 34:415–420, 2006.
7. Uz A, Ugur HC, Tekdemir I: Is the asterion a reliable landmark for the lateral approach to posterior fossa? **J Clin Neurosci** 8:146–147, 2001.
8. Yamashima T, Lee JH, Tobias S, Kim CH, Chang JH, Kwon JT: Surgical procedure "simplified retrosigmoid approach" for C-P angle lesions. **J Clin Neurosci** 11:168–171, 2004.

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COMMENTS

In this study, Hamasaki et al. used 3-dimensional (3D) computed tomographic (CT) navigation imaging to localize the projected surface landmark of the transverse-sigmoid (T-S) sinus complex in a small group of patients undergoing craniotomy as well as another group of patients undergoing cranial imaging for various other reasons. The authors report that traditional bony landmarks, such as the asterion, are not reliable landmarks for the T-S junction in the majority of patients and that a significant degree of variability exists among patients. The current study corroborates the findings of previous studies from our institution and others and further supports the concept that a more accurate landmark for the T-S junction is the intersection of the superior nuchal line and posterior edge of the mastoid. A line between the inion and root of the zygoma approximating the superior nuchal line and inferior edge of the zygoma should be identified on the surface before surgical draping and can be verified with imaging navigation procedures when available.

The authors report an innovative method for identifying individualized case-by-case surface landmarks of the T-S complex based on reconstruction CT imaging that may improve protection of the venous sinuses as well as limit unnecessarily extensive craniotomies. The extent and placement of each craniotomy in the 8 patients reported was verified with postoperative CT imaging and demonstrated the reliability of the reported procedure.

Gabriel Zada
Steven L. Giannotta
Los Angeles, California

The authors describe a relatively simple technique for exact localization of the T-S sinus junction. They use 3D CT imaging to project the T-S sinus complex onto the external surface of the cranium. The procedure consists of 3 steps: marking the sinus on the internal surface on 3D images of the cranium, transferring the marks to the external surface on axial images, and checking the transferred marks on the external surface of the cranium on 3D images. The accuracy of the technique was checked in 8 patients undergoing retrosigmoid craniotomies and showed good correlation with intraoperative findings.

As a second part of the study, a morphometric analysis using 3D CT bone images was performed in 30 patients. The distances between the inside corner of the T-S sinus junction and the asterion, root of the zygoma, mastoid tip, and inion were measured. This study showed that the asterion is not a reliable landmark for locating the underlying T-S sinus complex: the distance both to the superior nuchal line and to the posterior mastoid line were found to be highly variable. Therefore, the 3D CT–based procedure is proposed for planning a retrosigmoid craniotomy that may help to avoid the risk of sinus injury.

We would welcome any method that could increase the safety of the operative approach as long as it could be easily and reliably used intraoperatively. The crucial issue of the current report is how the authors transfer the information from the planning station to the cranium of the patient lying on the operating table. This stage is not presented clearly. The authors correctly point out that it is not always easy to pinpoint the location of the superior nuchal line on the cranial surface because the inion and the root of the zygoma are usually outside the surgical field. If they just extrapolate the data and rely on surface landmarks seen on the reconstructed 3D images, this would certainly decrease the reliability of the procedure. Furthermore, it was tested in only 8 patients. The authors should provide more information on the real practical significance of the technique.

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Hannover, Germany

This clinical study describes a method using preoperative 3D CT imaging to identify the external correlate of the T-S sinus complex (commonly thought to lie beneath the asterion) and measures the distance between it and the asterion. The procedure simply involves outlining the transition of the sinuses on the intracranial surface of a 3D CT depiction, translating these points to the external surface on axial 2-dimensional slices, and then identifying them on a 3D CT depiction of the external surface.

The authors claim that successful use of this procedure in 8 patients confirmed the reliability of the method. Their morphometric studies (bilaterally in 30 patients) showed significant variation in the relationship of the asterion and the sinus junction. They conclude that the asterion is not a reliable landmark for identifying the sinus junction and that their method is accurate and reliable.

This study addresses a common issue in planning a retrosigmoid craniotomy: placement of the burr hole. Previous studies have suggested that the intersection of the superior nuchal line and posterior mastoid line is preferable to the asterion as an external marker for the T-S junction. The authors' morphometric study found maximal divergences of the junction of approximately 25 mm from both the superior nuchal line and the posterior mastoid line. Their measurements showed that the asterion was above the sinus junction in 27% of cases and overlying it in 73%. These findings differ somewhat from those of a 3D CT venographic study, which found the asterion directly over the sinus junction in 51 cases, above the junction in 4 cases, and below the junction in 11 cases (1).

Although this study is of some interest, this 3D CT technique is unlikely to be widely adopted. It involves unnecessary operative time, cost, and patient radiation exposure in cases where stereotactic guidance is not otherwise needed (e.g., microvascular decompression), and magnetic resonance imaging is preferable for complex cases (e.g., cranial base tumors) in which stereotactic guidance might be helpful.

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1. Gharabaghi A, Rosahl SK, Feigl GC, Samii A, Liebig T, Heckl S, Mirzayan JM, Safavi-Abbasi S, Koerbel A, Löwenheim H, Nägele T, Shahidi R, Samii M, Tatagiba M: Surgical planning for retrosigmoid craniotomies improved by 3D-CT venography. **Eur J Surg Oncol** 34:227–2331, 2008.